CNN reconstruction of air shower events with TA FD

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Motivation

- Currently, FD is analyzed by the IMC method.
- IMC method is computationally time-consuming due to many of MC simulation.
- In the existing reconstruction, only one-dimensional parameters (such as X_{max}) can be obtained

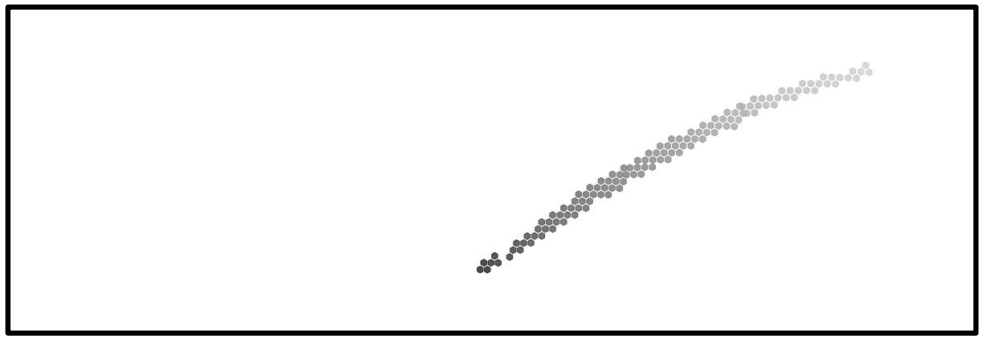
Development of reconstruction method by deep learning using FD event display as training data

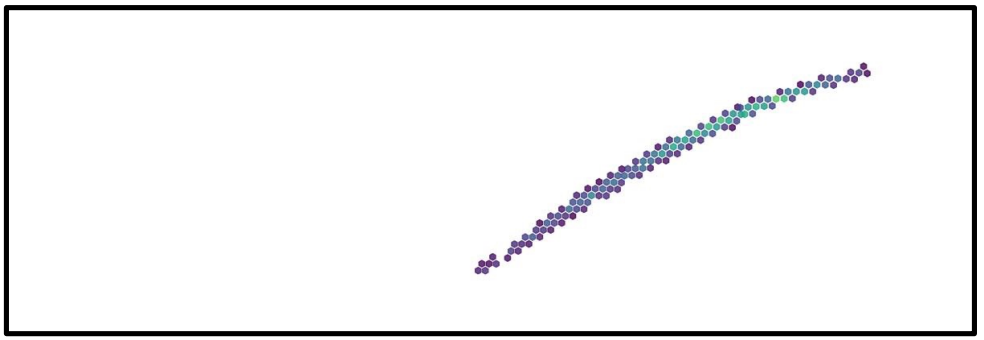
Research method

1. Air shower simulation to create pseudo data in the format as the actual data
2. Create event display from the created pseudo data
3. Create datasets for training from event display
4. Use the dataset to train the model to learn the features
5. Estimate air shower parameters from learned features
   ↳ Zenith, Azimuth, CoreX, CoreY, Energy, Xmax
6. Evaluate the model by comparing the estimated values with the true

Event display

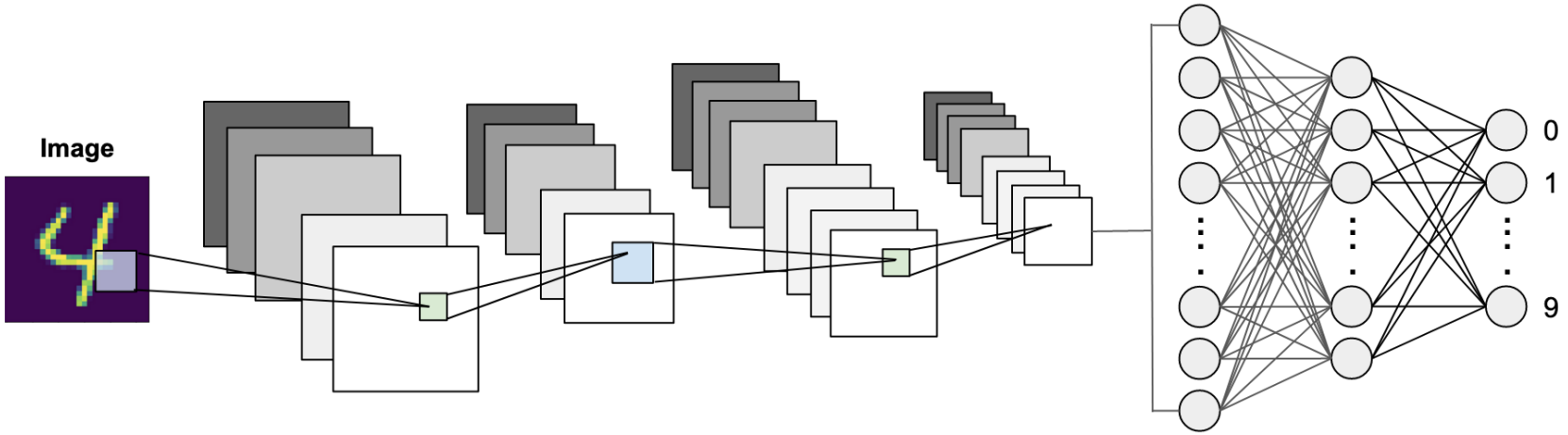
- event display images (96×32)
- The color map shows the passage of time, from blue to red
- The number of PMTs that detected signals is 15 or more, and the total number of PMTs detecting signals within each PMT camera is 128 or fewer





Model

- Using Python library : TensorFlow.Keras
- Using Model : CNN(Convolution Neural Network)
  -Models specialized for learning with images
  -Use convolutional and pooling layers for feature extraction



Previous Status

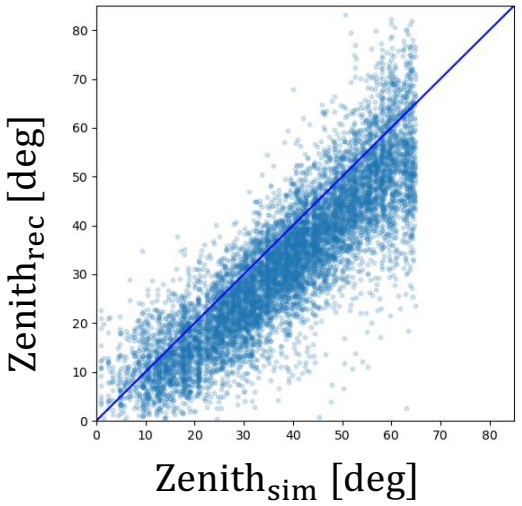
- geometry estimation results are
  as accurate as conventional reconstruction methods.

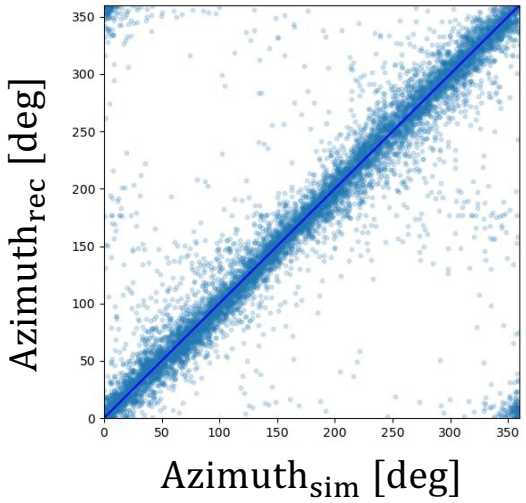
- No energy & Xmax estimation is possible.

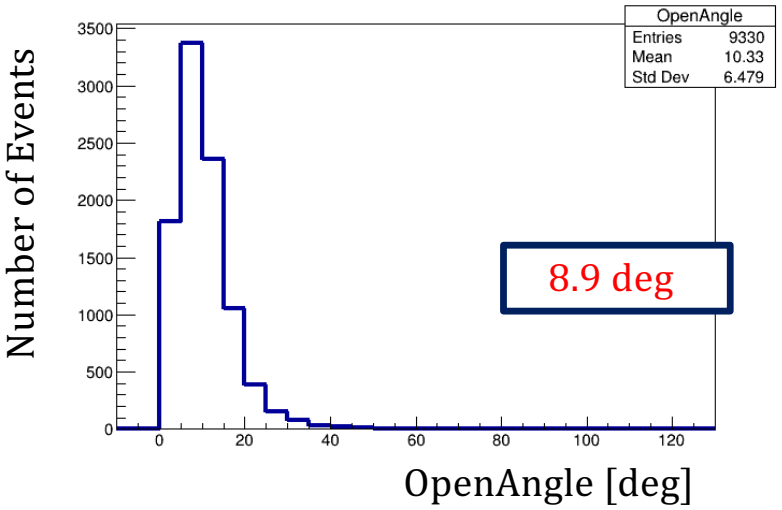
- To add energy & Xmax , I implemented a multi-input model to increase the number of features.

- Analysis with 6 parameters allowed learning of the core position, but failed to learn Zenith, Azimuth, energy, and Xmax.

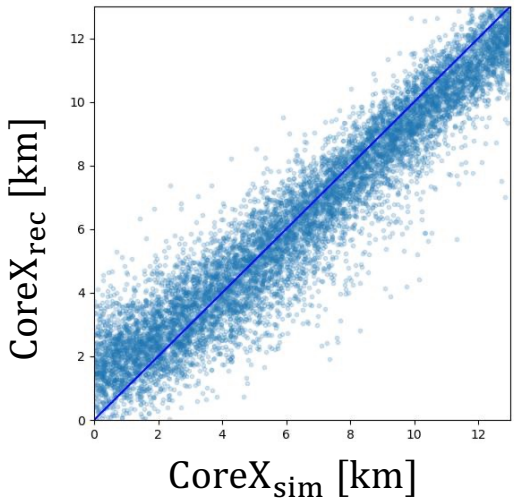
Analysis Results (Zenith, Azimuth)

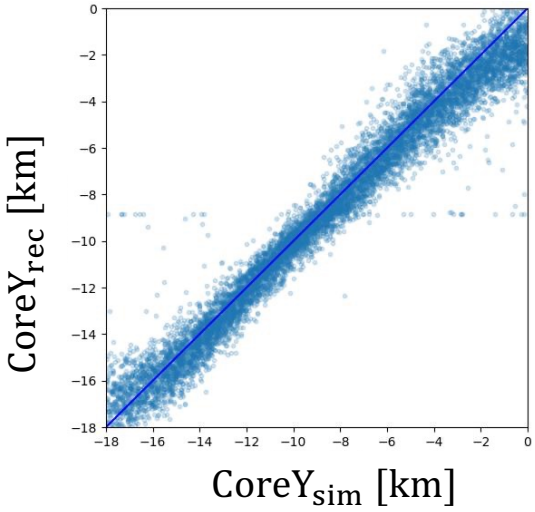


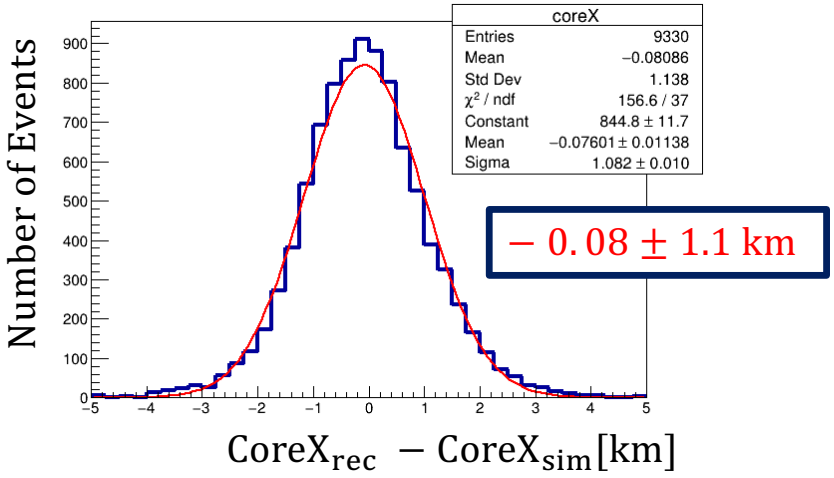


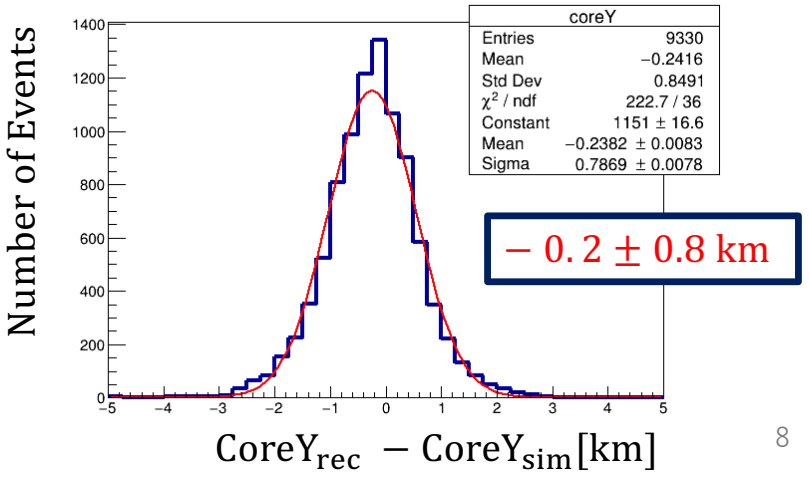


Analysis Results (Core)

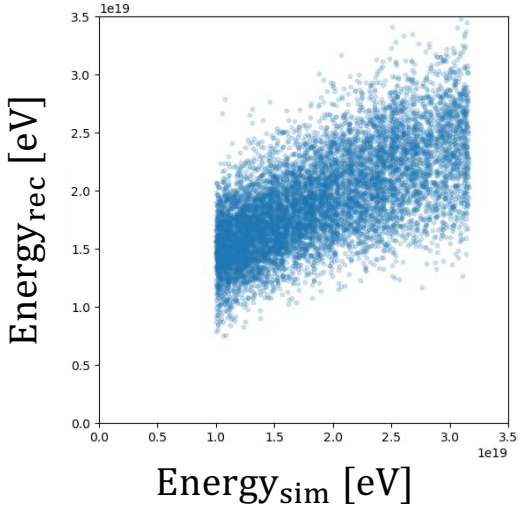


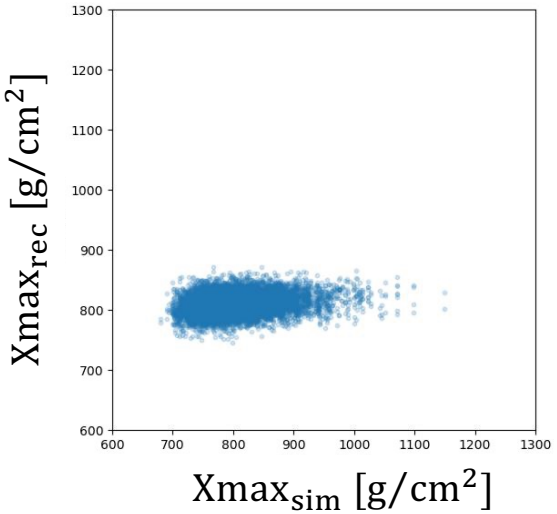


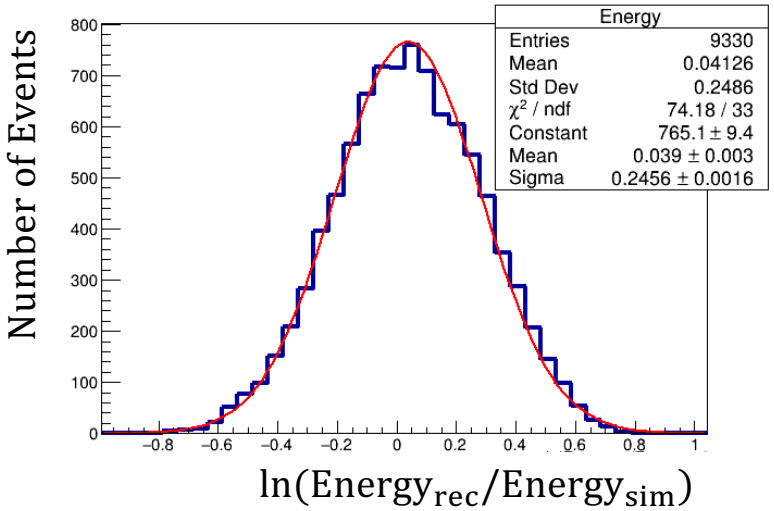




Analysis Results (Energy, Xmax)







Summary & Next to do

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- Debugging work was performed.
- The system has returned to its expected behavior, enabling parameter analysis.

Next to do

- Improve the model so that Xmax can learn.
- Prepare training data using CONEX and create a training model.

Back up

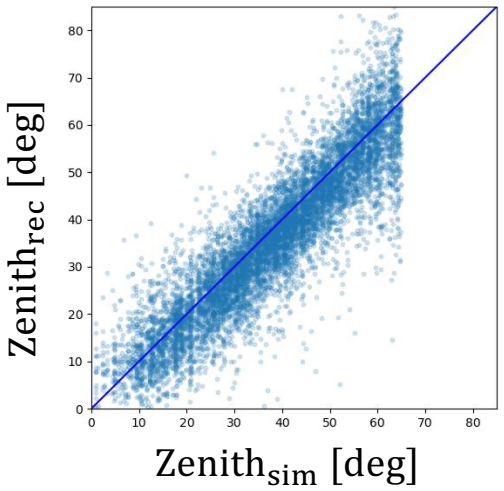
Simulation Conditions

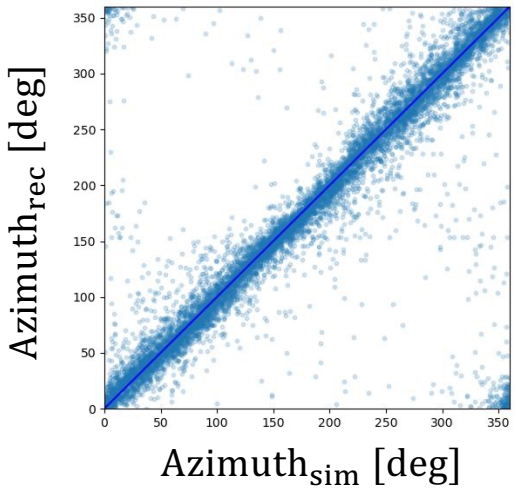
Training dataset	
19.0 ~ 19.1	10000 event
19.1 ~ 19.2	10000 event
19.2 ~ 19.3	10000 event
19.3 ~ 19.4	10000 event
19.4 ~ 19.5	10000 event
Event display create before	50000 event
create after	46762 event

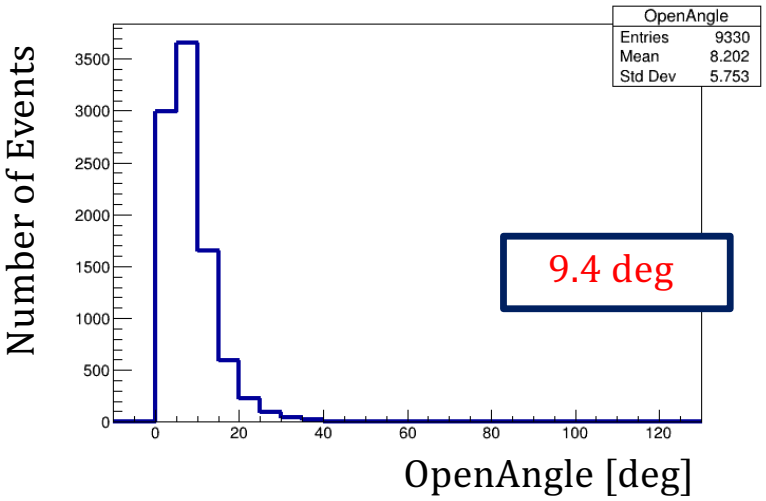
Test dataset	
19.0 ~ 19.1	2000 event
19.1 ~ 19.2	2000 event
19.2 ~ 19.3	2000 event
19.3 ~ 19.4	2000 event
19.4 ~ 19.5	2000 event
Event display create before	10000 event
create after	9330 event

particle type	Proton
FD Station	BR
Energy (log(E/eV))	19.0 ~ 19.5
Zenith	0 ~ 65
Azimuth	0 ~ 360
Core X (km)	0 ~ 13
Core Y (km)	− 18 ~ 0
coordinate origin	CLF
Missing energy	CORSIKA2009
Hadron interaction model	QGSJET-II-04

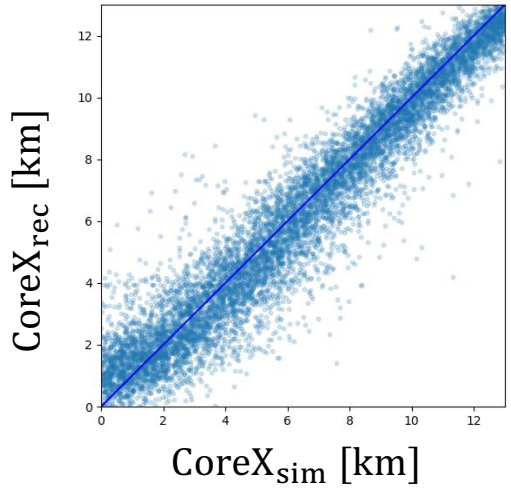
4Para Model Analysis Results (Zenith, Azimuth)

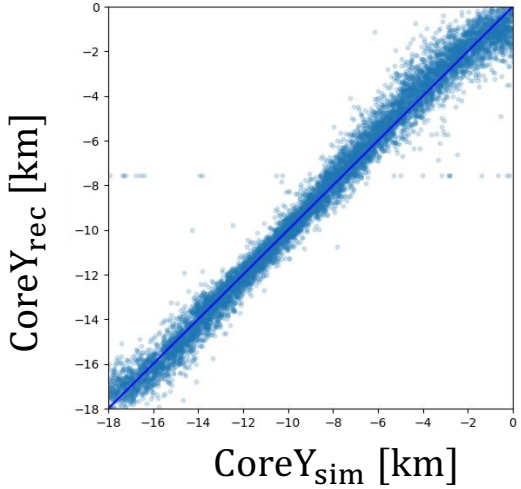


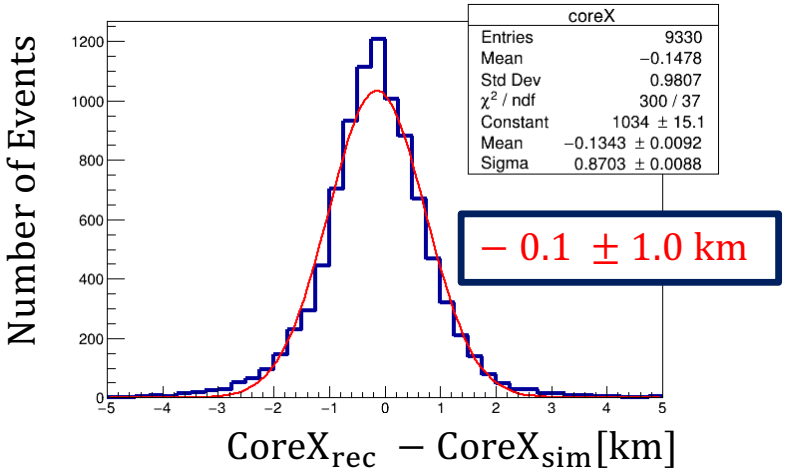


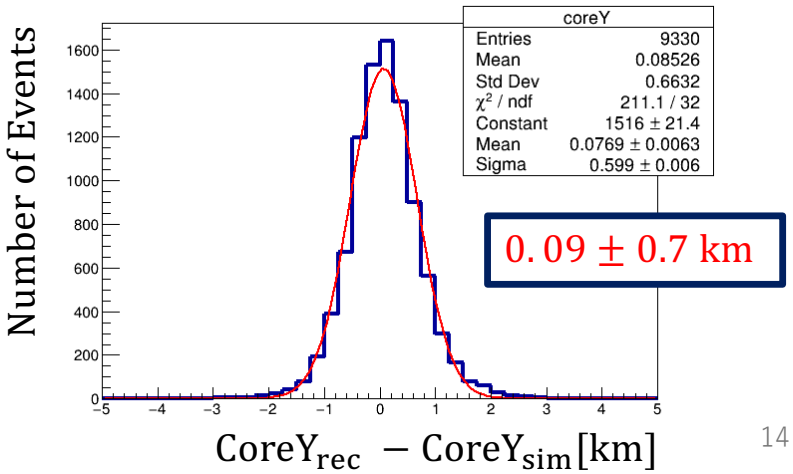


4Para Model Analysis Results (Core)









6Parameter Model